Investigation of the Rate of Shelf-Basin Interaction in the Arctic Ocean Using Radium Isotopes Collected from a Submarine

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LONG-TERM GOALS

My research goals lie in the utilization of naturally occurring radioactivity for the purpose of tracing the pathways and discovering the rates of various oceanic processes. Because naturally occurring radioisotopes have half-lives ranging from days to many years, it is possible to study processes that encompass a great variety of temporal and spatial scales. This has also given me the opportunity to be involved in studies crossing over different disciplines of oceanography.

Relevant to this work, I apply short-lived isotopes (<10 year half-life) to trace the movement of water and associated properties (e.g. heat, mass) in the upper ocean both in the horizontal and vertical dimension. Such work has been directed to study in areas of mid-ocean gyres (SUBDUCTION Program), coastal zones (CTZ, SBI programs) and high-latitude (SHEBA, SBI). Another area of interest has been the study of geochemical processes associated with the mid-ocean ridge spreading systems. I have used radioisotopes to constrain the residence time of the hydrothermal fluid within the ocean crust, to evaluate the chemical changes within the spreading hydrothermal effluent plume, and to examine the growth rate of associated sulfide deposits.

OBJECTIVES

The largely landlocked Arctic Ocean is strongly influenced by processes occurring on its adjacent continental shelves. The shelf waters, modified by biochemical and physical processes, eventually feed the polar mixed layer and/or ventilate the subsurface layers of the interior basin, and products of biogeochemical interactions within the shelf environment are transferred into surface and subsurface layers of the Arctic Ocean. The shelves profoundly influence the thermohaline structure and maintenance of the ice cover of the Arctic Ocean. There is transfer of western Arctic shelf-derived carbon and nutrients to the Canada Basin but the fate of recently sequestered carbon produced on the shelves is poorly known. The relative forms of carbon being transported off the shelf depend in part on the rate of water exchange with the interior basin, but this is not well parameterized. Recent studies indicate increased levels of anthropogenic contaminants, introduced from the shelves from river outflow, but again, assessment of this impact depends on knowledge of the exchange rate between the Arctic shelves and the interior basin. A better understanding of the processes and rate of exchange with the central basin is clearly needed. To this end, we are utilizing an isotopic tracer technique to investigate the rate of exchange between the Arctic shelves and the Arctic Ocean interior. The

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14. ABSTRACT
My research goals lie in the utilization of naturally occurring radioactivity for the purpose of tracing the pathways and discovering the rates of various oceanic processes. Because naturally occurring radioisotopes have half-lives ranging from days to many years, it is possible to study processes that encompass a great variety of temporal and spatial scales. This has also given me the opportunity to be involved in studies crossing over different disciplines of oceanography.

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technique utilizes the measurement of the water column ratio of two naturally occurring radium isotopes, $^{228}Ra/^{226}Ra$. Because these species are derived from input from the shelf sediments, their relative distribution in the shelf and basin water have proven to be very valuable in assessing the degree of shelf-basin interaction

The water for this project was collected through the seawater intake of the nuclear submarine USS Mendel Rivers at a depth of approximately 150m as part of the SCICEX program. This will allow the important upper halocline transport of the Arctic Ocean to be investigated.

APPROACH

To trace the shelf-water interaction and transport to the central basin we are utilizing the measurement of the ratio of two isotopes of radium, ^{228}Ra ($T_{1/2}$ =5.77y) and ^{226}Ra ($T_{1/2}$= 1620 y) in the water column extending from the shelf into the central basin. Radium is derived from the decay of thorium in the sediments. Radium-228 is produced from the decay of ^{232}Th, and ^{226}Ra from the decay of ^{232}Th. Because radium is mobile in the porewaters of sediment, a fraction of the radium produced there diffuses into the overlying water. Therefore, enrichment of Ra isotopes occurs in marine waters when they are in contact with sediment. Waters crossing shelves will therefore pick up radium diffusing from the underlying sediments. The $^{228}Ra/^{226}Ra$ ratio over the shelves will be high, because the newly injected ^{228}Ra will not have decayed to a great extent. However, because of the short half-life of ^{228}Ra, as the water is transported offshore, the $^{228}Ra/^{226}Ra$ will decrease because of radioactive decay (radioactive loss of the long-lived ^{226}Ra in the relevant timescales is negligible) and mixing with open ocean water with very low ^{228}Ra. Note that the use of the isotopic *ratio* precludes complications arising from possible biological or particle uptake of the radium.

The distribution of $^{228}Ra/^{226}Ra$ provides i) a signature of the water masses that have been in contact with the shelf sediment, ii) information on the residence time of the water masses on the shelves; and iii) information on the transit time of the water masses since they detached from the shelves.

The water for this project was collected through the seawater intake of the nuclear submarine USS Mendel Rivers at a depth of approximately 150m. Radium isotopes are collected on manganese - coated acrylic fibers that adsorb radium isotopes efficiently and without fractionation. In the process, approximately 200 L of seawater are slowly drained through plastic cartridges filled with the Mn-fiber. The fibers are subsequently stored until processing on land. In the laboratory, fibers are sealed in small plastic petrie dishes where, in this form, the $^{228}Ra/^{226}Ra$ activity ratio is determined by measuring the activity of the radium daughters by gamma ray spectrometry. The counting system is calibrated with known radioactive sources in a geometry that matches that of the fiber samples.

WORK COMPLETED

In October 2000, 46 samples were collected along a transect across the western Arctic Ocean at depth of approximately 150 m. At this time we have completed analysis on 11 of the samples and these values ($^{228}Ra/^{226}Ra$ ratios) are superimposed over the SCICEX track (figure 1).

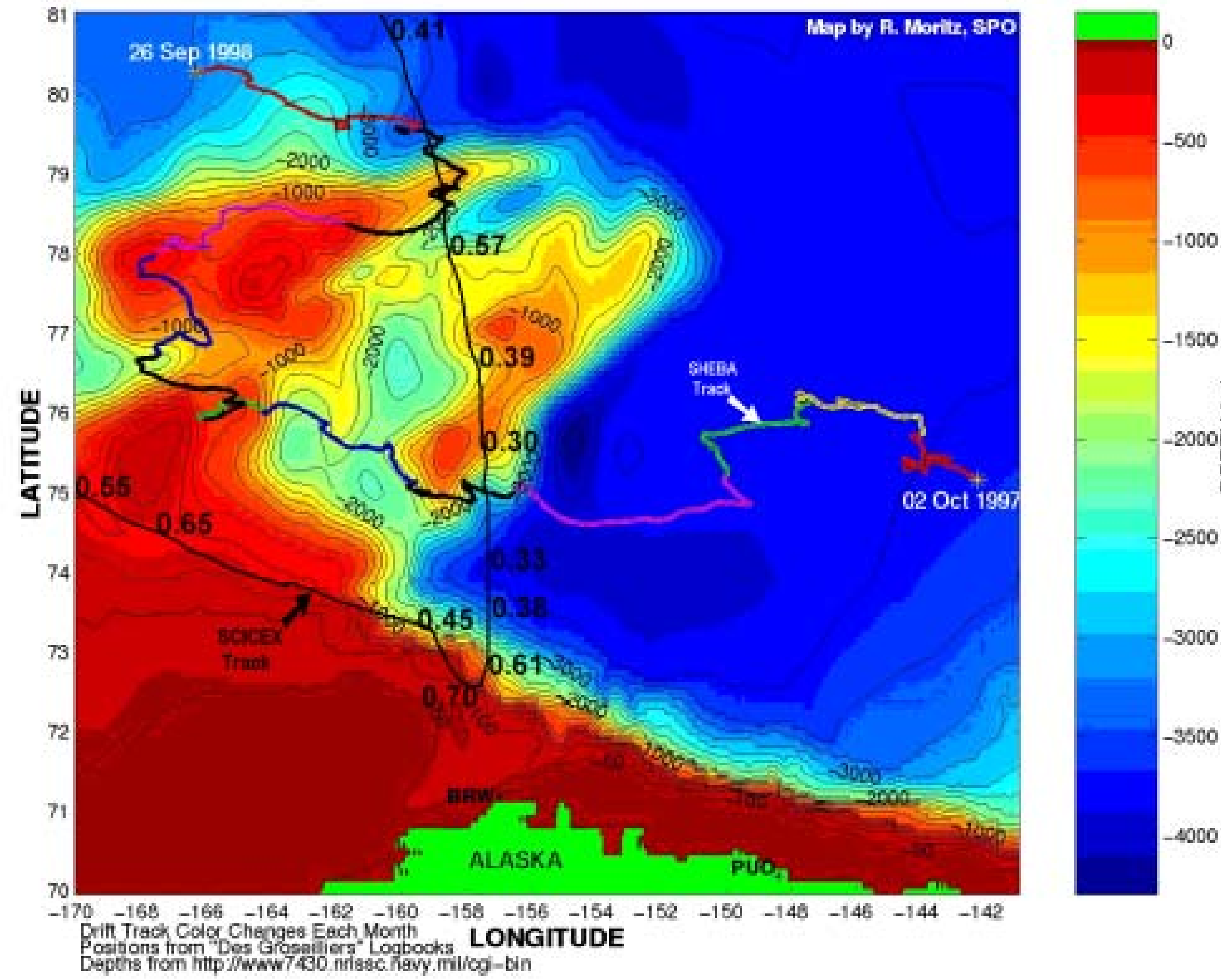

Figure 1. The SCICEX track in the western Arctic where samples were collected from a depth of approximately 150m. The track runs approximately along 157°W from 81°N to 73°N then veers northwestward. The $^{228}Ra/^{226}Ra$ ratios are superimposed over the SCICEX track. Values range from 0.30 to 0.70.

RESULTS

The $^{228}Ra/^{226}Ra$ ratios superimposed over the SCICEX track have values ranging from 0.30 to 0.70. The small number of samples analyzed thus far precludes extensive interpretation. However, it is apparent that these samples from 150m reflect the pattern observed from surface observations by the PI made during SBI PHASE I. That is, the higher values seem to be derived from initial shelf input that is subsequently advected in an anticyclonic manner around the Beaufort Gyre. Values within the gyre, although associated with the halocline, appear to have more sluggish transport. This picture will be enhanced as our data set is completed.

IMPACT/APPLICATIONS

The data collected in this project will establish timescales for comparison to other measurements that will be made in the SBI program such as carbon, nutrients and plankton species. These timescales will allow the rate of change of these constituents to be established as transformations occur during shelf-basin transport.

TRANSITIONS

The data collected in this project will establish timescales for comparison to other measurements that will be made in the SBI program such as carbon, nutrients and plankton species. These timescales will allow the rate of change of these constituents to be established as transformations occur during shelf-basin transport. This data will be readily available to the participating scientists in the upcoming PHASE II SBI field program.

RELATED PROJECTS

The measurements made in the context of the SCICEX expedition have direct bearing to the isotopic measurements we are making during the SBI program. Together, these measurements will provide an unambiguous tracer of shelf-interaction on collected waters and help establish the timescales of transformation of the other constituents (e.g. carbon, nutrients, organisms) being measured by investigators during the SBI program.